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ESTIMATION OF RAILWAY BELGRADE RING OPTIC NETWORK USING NETWORK PLANNING TOOL

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Abstract *– The communication networks in railway environment demand quick adjustments and flexible approach to end user needs. This requires previous check-up of fallout scenarios' in networks prone to vulnerabilities. Currently evolving communication network (particularly the Belgrade ring) is an interesting case, whose implementation will go through phases. The availability of completed phases would be compromised in case of cable failure, not being an isolated case in practice. The use of software could make some of the fallout scenarios a bit clearer and thus the expected consequences less devastating, making the maintenance teams more prepared. This paper uses one of the open source free network planning tools (net2plan) for such estimation. Since only a few of the spans of interest have been equipped with fiber-optic cables the number of phases of cable routing combinations is significant. However, some are more likely to be laid out earlier, so certain estimations are made in order to further study these scenarios.*

Keywords – fiber optic network, Belgrade ring, net2plan tool

1. INTRODUCTION

Use the option "mirror margins". Margins: upper, lower and left 20 mm, right 15 mm. Text should be divided onto two columns (85 mm wide) with 5 mm spacing between columns. Columns should be justified. The text in the whole paper should be in Times New Roman, font size 11 pt, unless it is not noted otherwise. Use single spacing. Retract the first lines by 5 mm. No empty lines between paragraphs.

Number of railway lines originating from Belgrade are numerous. Belgrade as a substructure in a greater network is complex. The ongoing projects of development and reconstruction of railway lines mostly incorporates the layout of fiber optic cables for the future optic network. These projects related to permits are geographically bound and even though there are some guidelines for the mutual order of completion various field conditions often render this order useless as projects expected later are finished earlier and vice versa. The Belgrade ring is chosen because of a number of higher order nodes in the ring and a great number of branches (lines, traffic, ..), thus beeing a good representative of the possible problems in the overall network. From the known ongoing projects (designs) it is possible to have some idea of this order of completion, using some of the assumptions. Further in this paper line will represent the railway line we acknowledged, which could be part of one or several official railway lines in Serbian railway network, and the lengths used in model will be actual lengths along the line between nodes according to as – build layout plans. In all fibre spans in ongoing designs railway is planning also a tube with G.655 fibers [1]. The fig 1. shows the order of completion of the railway spans of interest. One line is already equipped with fiber optic cables – Belgrade center (BG.C.)– Karadjordje's park - Pancevo Bridge– Ovca – Pancevo (PA). This line further travels to Vrsac (VR), and that part of the line is not equipped but for this estimation, we assume it is. Second line that was taken into account is the ongoing project Belgrade center (BG.C.)– New Belgrade– Zemun (ZE) – Batajnica (BA) – Novi Sad (NS). This line is branching in Indjija towards SID (shown in fig.1). Third line is the part of Belgrade ring with numerous important points Belgrade center – junction G – Rakovica (RA) – Resnik (RE) and two

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interconnections form Rakovica and Resnik to Belgrade Marshalling Yard (BG.M.Y.). The major national railway lines travel further form this nodes – South 1 (S1: Lapovo – Nis) from Resnik, South 2 (S2: Mala Krsna – Velika Plana – connection to S1), and a line towards Bar (i.e. Valjevo – Pozega – Podgorica – Bar). Fourth line is the western part of the Belgrade ring and it incorporates Belgrade Marshalling Yard – Ostruznica - Surcin – Batajnica (BA). This part of the BG ring is used mostly for freight and as this traffic increases will gain in its significance. Some of the mentioned locations are not nodes in this estimated networks, they mainly serve to give the better understanding of the true line topology.

Fifth and sixth line currently not exist nor are they part of the ongoing projects but are a reality. Studying the map of Belgrade these two lines look highly probable. Fifth line Resnik –Vinca- Pancevo could be realised only through the major national project, being a line that needs the bridge over Danube, as well as a sixth line Pancevo -Batajnica (the interconnecting stations are not noted because there are no reference to relate to).

The future existence of these two lines and the order of their completion are few of the major assumptions in this paper. Node Belgrade Nemanjina, being the administrative center of Serbian railways is not shown in fig.1. Belgrade Nemanjina is currently connected to Belgrade center with fiber optic cable, with no possibility of forming a metropolitan subring, entirely within railway infrastructure. This node will not be included in this estimation.

There is no General plan in force for the finalized railway communication network so the capacities i.e. traffic matrix of all level nodes will have to be estimated, too. This is a main reason why the fig.1 contains information not only about the nodes in the ring but about the further going main railway lines giving thus the information about the future significance of the lines.

One of the intricacies of the railway network are flat rings and rings on the railway line formed using fiber optic on the opposite sides of the tracks. Double-sided fiber links are good practice on lines where ETCS Level 2 (European Train Control System – part of the European Railway Traffic Management System i.e. ERTMS) systems are designed. WDM systems are part of the ongoing designs and IP traffic leaning on WDM are expected throughout the departments [2].

ZE, BG.M.Y and BG.C. are nodes with a significance in the BG ring since it is a reality that in Belgrade most of the control, maintenance and surveillance centers will be places. It is also easier to make one of these nodes a disaster recovery center (BG.C. not a likely candidate because of the shortage of space).

2. MODEL AND THE NETWORK DESIGN OF THE BELGRADE RING IN NET2PLAN

Model and network design of the Belgrade ring are established using certain assumptions and the free

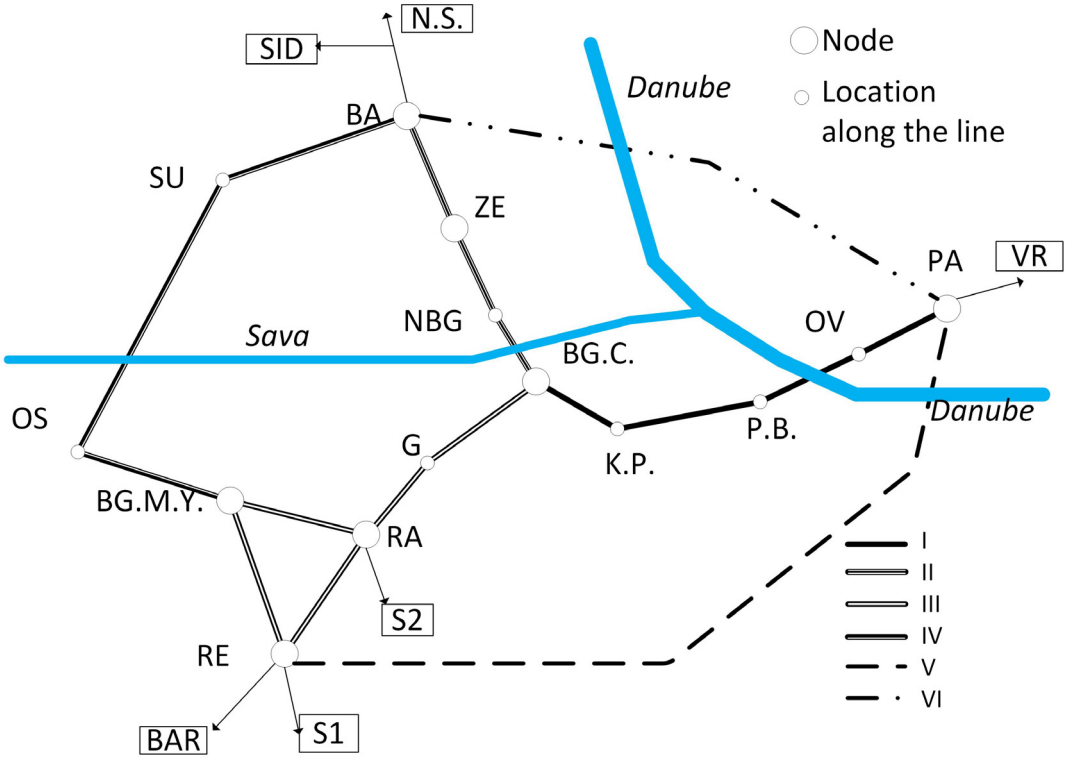

Fig.1. Belgrade ring, lines in it and its nodes relevant to this estimation.

Net2Plan open-source multilayer network planned and simulator (free Java tool) software version 0.6.6.0 [3].

Net2plan delivers reports according to set model. The objects crucial to model are: nodes, links (belonging to different layers), traffic demands, multicast traffic demands, multicast trees, routing of unicast traffic, resources, shared-risk groups.

Communication networks are organized into layers, defined by protocols and departments. The upper layers are connected trough optical connections of fixed capacity in the software i.e. lightpaths, representing direct links (making them the path of optical fiber in the underlying layers along the route). Lightpaths are assigned wavelength, not changing along the route (uni/bidirectional channels). Optical Add/Drop Multiplexers (OADMs) are forwarding lightpaths thus being the optical switching nodes. The network layers are: link, demand, route, forwarding rules, multicast demand and multicast tree. Nodes, resources and shared – risk groups are not assigned to any particular layer [4].

Since this paper deals with the fiber network there are no real demands on the upper layers (i.e. IP layer). So the fig.2 shows only links on the WDM layer, and the IP layer is off. (fig 2. is in correspondence to fig.1). The lines with fibers along both sides of the tracks are chosen to be BG.C. – BA and BG.C. – RA-RE as these lines will be ETCS L2 lines.

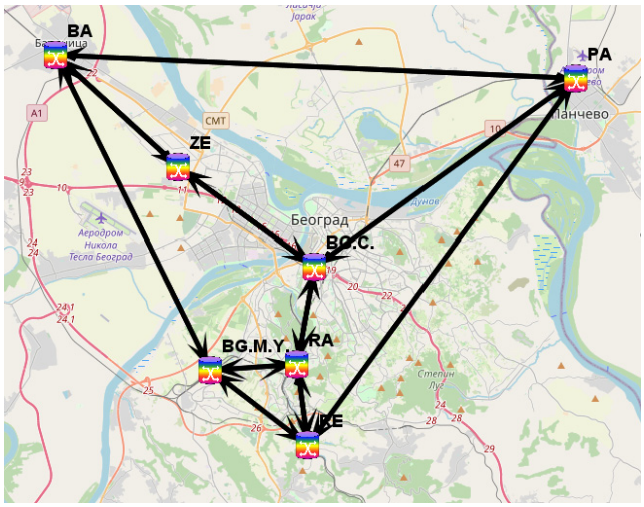

Fig.2. WDM layer

The distances in the BG ring are not lengths that need line amplifiers. Distances on railway lines (SID, NS, BAR, S1, S2) are greater but these lines going further from BG ring, are here mentioned only to avoid BG ring to look like an island in the overall railway network as well as to point out the complexity of the BG ring exit nodes (BA, PA, RA, RE) in terms of installed equipment.

Model envisages the use of generic OADMs and their parameters offered by software. The used WDM range is 193.1 – 197.09 THz (~4THz) with the distance of 12.5GHz [5]. Directionful Add/Drop modules with passive mux/demux elements are with losses of 0.6dB and PDM with 0.5 ps/√km (polarization mode dispersion). Chromatic dispersion CD is set to 15 ps/(nm·km). Attenuation is set to 0.25dB/km. The chosen architecture (terms used in Net2Plan user manuals and documentation) is *broadcast-and –select*. Some of the nodes are particularly complex with 3-5 lines originating from them. This will not be commented further in this paper since those issues must be addressed during real designs and implementation.

On the WDM layer chosen lightpath requests are symmetrical and are a complete mash (all to all) thus giving the bidirectional lightpath request between all nodes with preset line rate 100Gbps and 1+1 protection. Lightpaths are set to be with shortest path in optical latency.

Fibre fallout scenario that was the aim of this paper is basically a sequence of fibre disconnections resulting in the critical network state. There are two approaches that we recognize. First is a state in which not all lines are finished so a full connection state of the nodes is not achieved. The other is if the full network is in work but the main lines are falling out. This means the fibre (link) between adjacent nodes is disconnected (bidirectional fiber link).

3. REPORTS AND RESULTS

Using the *ReportNiw_wdm_routingSpectrumAnd ModulationAssignments* report summary of spectrum occupation information are achieved. Report shows routing and spectrum occupation of the lightpaths in the network. Namely the report indicates the use of 28 fibers, 42 lightpaths (and additional 42 for 1+1 protection). Shown as min/average/max there are 5/32.18/89.25 lightpaths in km and 1/1.9/3 lightpaths in num hops.

Another report is generated in the GUI of the Net2Plan - *ReportNiw_wdm_lineEngineering*. This report shows line engineering information for WDM links in the network. This report generates basic checks for each link and lightpaths (signal power levels, chromatic dispersion, OSNR,..).

With the previously mentioned default values set in the Net2Plan the attenuation on all links (fiber - node to node) has not exceeded 12dB. The net CD is 675 ps/nm for the longest line in model (RE-PA and vice versa). The line with significant CD are also lines BA-PA (525ps/nm) and BG.M.Y. – BA (450ps/nm). This is expected. *Lightpaths* subtab shows no crashing is evident (the bidirectional lightpaths occupy same slots). Signal metric at the transponder show Rx power that is too low for all lightpaths (mandatory range is -20÷10dBm, which is a consequence of passive elements attenuation. This is fixed with a number of amplifiers inserted to compensate this attenuation of passive elements within OADMs.

These amplifiers – boosters and preamplifiers are added into *Fibers* tab. The gain of these initial and end node amplifiers are set to have gain of 15dB for boosters and preamplifiers are set to have gain of 20dB to achieve levels within the sensitivity range at the Rx side. This have stabilized the levels so a report was further clear of unsolved issues.

The fiber network fallout scenario commented in this paper is as mentioned in table 1 (second approach). The table gives the studied disconnections of fibers in BG ring. The table does not treat all fibre links on a line but instead represent only one fibre link in a line and if possible middle one. If there are two fibre links than the link closer to BG.C. is chosen.

*Tab. 1. Fallout scenario for fibre network. If the indicated lightpaths are backups the mark (**b**) is used.*

No.	Fibre out (bidirectional)	Lightpaths (bidirectional) out (backups/not)
1.	ZE – BG.C. (one side of the tracks)	ZE-BG.C. (**b**), BG.M.Y.-BG.C. (**b**), BG.C-PA (**b**)
2.	ZE – BG.C. (both sides of the tracks)	BA-BG.C, BA-RA (**b**), BA-PA (**b**), ZE-BG.C, ZE-BG.C(**b**), ZE-RA, ZE-BG.M.Y (**b**), ZE-RE, ZE-PA, BG.C-BG.M.Y(**b**), BG.C.-PA (**b**)
3.	ZE – BG.C. and BG.C. – RA (one side of the tracks)	BA-RA (**b**), ZE-BG.C. (**b**), ZE-BG.M.Y(**b**), BG.C.-BG.M.Y(**b**), BG.C. -RA(**b**), BG.C.-PA(**b**), RA –PA
4.	BG.C. – RA (both sides of the tracks)	BA-RA (**b**), ZE-RA, ZE – BG.M.Y (**b**), ZE-RE, BG.C-BG.M.Y, BG.C. – R, BG.C-RA(**b**), BG.C-RE, RA-PA

4. CONCLUSION

The Net2Plan offered enough options to confirm or discard presumption used for this model. The used values and setting are generic enough to assume the given results cover majority of vendors (WDM, fibers). The good railway practice related to double sided fiber line layouts is resilient enough which is shown in the results. This combined with the 1+1 protection is enough for the BG ring to survive chosen fallouts. On both lines that carry the most of the railway and communication traffic BA-BG.C. and BG.C. – RA-RE disconnection of fibers on only one side of the tracks results also in a still functioning network.

It would be beneficial to compare these results to proprietary software of different vendors with real parameters of WDM equipment and fiber optic cables.

Comparison to results of the first approach to fallout fibre network scenario could point out some weak spots in the design also. Thus a more accurate state of unfinished network could be shown with more recognized steps in implementation. These results also point out a necessity for a General plan of complete fiber optic network with appropriate traffic matrices for different demands / departments / subsystems in railway communication network.

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